

## **On the Detection of Motion Relative to the ‘Ether’**

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*From the classical perspective, it is well known that the use of the Lorentz’s Contraction of bodies in the direction of motion explains the null results reported by Michelson & Morley in their famous experiment (and all successive repetitions). In this paper, taking into account Lorentz’s Contraction, we show how a one-way interferometer can be used to detect anisotropies in the speed of light, detecting changes in the interference pattern when the interferometer is rotated. The magnitude of these changes is proportional to the speed of the interferometer relative to the ‘ether’.*

### **Introduction**

Before Young’s experiments in the 19th century, when he made interfere two light wave fronts, many experiments had been already done with the purpose of determining various properties of matter and light itself.

Given that many experiments demonstrated the wave-like nature of light, and therefore the belief that light propagated through a physical medium, during the 19<sup>th</sup> and 20<sup>th</sup> century many different experiments were made to find this medium, so called “*luminiferous ether*”.

The postulation of Maxwell Equations of Electromagnetism (1865) encouraged further the search of the ‘ether’, because it was needed to find the medium over which light propagates with speed ‘c’, predicted in the derived electromagnetic wave equation.

As it is today generally accepted, such ‘ether’ has never been found. All experiments have been reported null or results obtained have been *much less than expected* (as for example the very famous Michelson and Morley Experiment in 1887). Among many, experiments claim to have reduced the existence of the ‘ether’ with wonderful precision [1].

*Before* the Special Theory of Relativity (STR) was postulated by Einstein in 1905, the scientific community had theories that explained the null results obtained in the experiments in search for the

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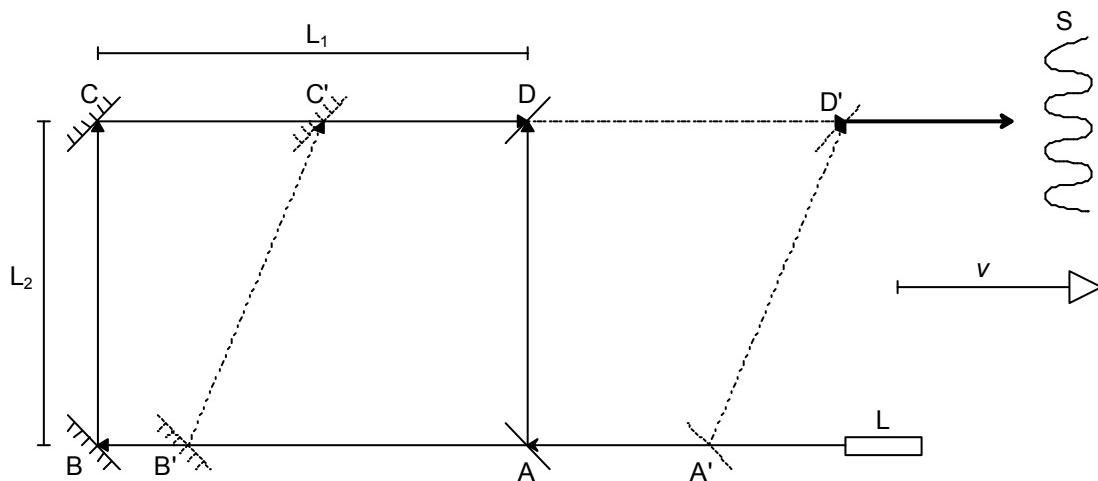
'ether'. Michelson & Morley's (M&M) results were explained by Lorentz, introducing his well known transformations, predicting a contraction of bodies in the direction of their motion (or, equivalently, perpendicular expansion). This is known as Lorentz's Contraction.

In 1905, Einstein postulated the Special Theory of Relativity (STR), which had great success among the community of physicists, and that also explained the results of the M&M experiment, as well as all previous null experiments. Although analogous formulations of the Lorentz's contraction can be obtained as a result of Einstein's postulates, the interpretation of the results differs greatly.

In Einstein's perspective, the 'ether' doesn't exist, there is no relative motion between light and observer. The observer always measures the speed of light as the universal constant, 'c'. In Lorentz (or classical physicists) perspective, the 'ether' does exist as the medium over which light propagates. Hence, for an observer moving relative to the 'ether', the speed of light relative to the observer is different from 'c'.

On the next formulations, the Contraction of Bodies in the direction of motion is considered as *ad-hoc* principle. It is shown that changes in the interference pattern can be obtained when an interferometer as the one proposed is rotated.

## Theory



**Figure 1 Interferometer by which calculations are made. Solid lines represent the interferometer at rest, while dotted lines represent the path light travels when the interferometer moves with  $v>0$ .**

Consider an interferometer as the one shown schematically on Figure 1. When analyzed at rest, light emitted by the source located at  $L$  reaches beam splitter located at  $A$ . One beam travels the optical path between points  $ABCD$ , while the other travels  $AD$ . Both beams recombine at  $D$ , and the interference pattern can be seen on the screen  $S$ . When the interferometer travels at a speed  $v$  with respect to the ‘ether’, while the beam of light travels from  $A$  to  $B$ , the mirror at  $B$  moves to position  $B'$ . In this fashion, one beam travels  $AB'C'D'$ . For both beams to recombine at  $D'$  at the same time, the second beam must travel the path  $A'D'$ .

To obtain the time taken by each beam to reach  $D'$ , one has to consider Lorentz’s Contraction of

bodies in the direction of their motion. We express this factor with the parameter  $\alpha = \sqrt{1 - \frac{v^2}{c^2}} < 1$ ,

where  $c$  is the speed of light, and  $v$  is the speed of the interferometer, both relative to the ‘ether’.

The time taken by light to travel paths  $AB'C'D'$  and  $A'D'$  (subscripts 1 and 2, respectively) is given by:

$$t_1^1 = \frac{2L_1}{\alpha c} + \frac{L_2}{\alpha c} \quad (1)$$

$$t_2^1 = \frac{L_2}{\alpha c} \quad (2)$$

$$\Delta t_1 = t_1 - t_2 \quad (3)$$

For equations (1) y (2), we have used Pythagoras’s Theorem with the relation

$(vt_{B'C'})^2 + (L_2)^2 = (ct_{B'C'})^2$ , where  $t_{B'C'}$  is the time taken by light to travel from  $B'$  to  $C'$ ;  $t_{B'C'} = t_{A'D'}$

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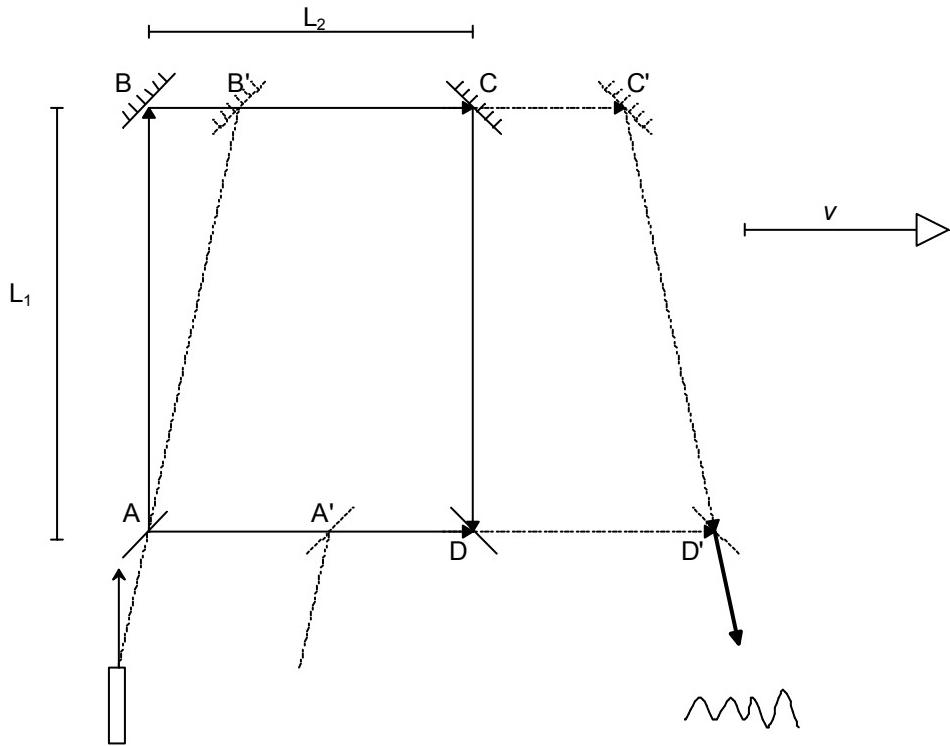


Figure 2 Same interferometer, after a 90° rotation.

Using Figure 2, when the interferometer is rotated 90° (superscript 2), we have for the travel times:

$$t_1^2 = \frac{2L_1}{\alpha c} + \frac{\alpha L_2}{c - v} \quad (4)$$

$$t_2^2 = \frac{\alpha L_2}{c - v} \quad (5)$$

$$\Delta t_2 = t_1^2 - t_2^2 \quad (6)$$

We can then find that

$$\Delta t = (\Delta t_2 - \Delta t_1) = 0 \quad (7)$$

The result obtained in equation (7) is the expected one, and is a direct consequence of considering Lorentz Contraction  $\alpha$ .

It is important to notice that, although  $\Delta t = 0$ ,

$$t_1^2 > t_1^1 \quad (8)$$

And that

$$t_2^2 > t_2^1 \quad (9)$$

That is, the time taken to travel  $AB'C'D'$  or  $A'D'$ , in the first orientation (before the  $90^\circ$  rotation) is *smaller* than the time taken to travel the same paths in the second orientation of the interferometer (after the  $90^\circ$  rotation). Equivalently, the distance traveled by each beam in the first orientation (Figure 1) is *smaller* than the distance traveled by each beam in the second orientation (Figure 2).

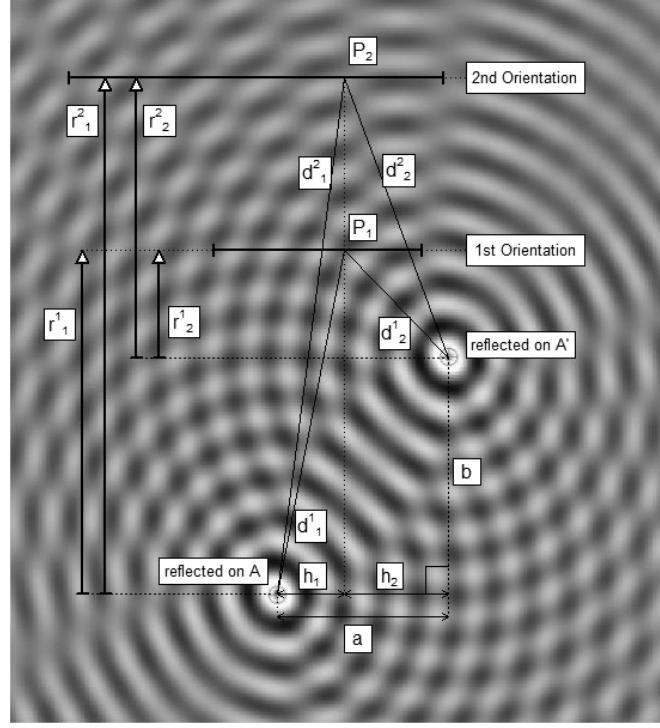
This important result explains why the interferometer is sensitive to anisotropies of the speed of light when the interferometer is rotated.

It is important to emphasize that the results obtained in equations (8) and (9) are not obtained when using a M&M type interferometer, because light travels each arm in a *two-way fashion*, thus obtaining  $t_1^2 = t_1^1$  and  $t_2^2 = t_2^1$ .

It is interesting to see that  $\overline{AA'} = v \frac{2L_1}{\alpha c}$  has the same value for both orientations. This expression

means that the interferometer has moved with speed  $v$  during the time  $\frac{2L_1}{\alpha c}$ .

We can now obtain the expression for the phase change in an observation point in the last beam splitter ( $D'$ ) as a consequence of the rotation of the interferometer.



**Figure 3 Schematic behavior of the interference produced by the reflection on A and A'.** The points P<sub>1</sub> and P<sub>2</sub> represent the position of the observer in each orientation (rotation of the interferometer of 90°). In the figure, after the rotation, the observer can see the pattern changing approximately 1 fringe.

Figure 1 and Figure 2 show a perfectly aligned interferometer. In practice, in order to be able to observe interference fringes, the interferometer must be slightly unaligned. That is, the angles of the mirrors and beam splitter don't have exact 45° inclinations. The width of the interference fringes depends directly on the degree in which the interferometer is unaligned. In Figure 3, this effect is represented by the separation  $a = h_1 + h_2$  of the hypothetical light sources equivalent to the reflections on A and A'. On

Figure 3, the superscript  $i = 1, 2$  denotes the first and second orientation, respectively; the subscript

$j = 1, 2$  denotes the paths  $AB'C'D'$  and  $A'D'$ , respectively. The lengths  $|\vec{d}_j^i|$  of the optical paths

$\overline{AB'C'D'}$  and  $\overline{A'D'}$  are equal to  $|\vec{d}_j^i| = \sqrt{\left(\left|\vec{r}_j^i\right|\right)^2 + (h_j)^2}$ , where  $|\vec{r}_j^i| = ct_j^i$ ; when  $a = 0$ ,  $|\vec{d}_j^i| = |\vec{r}_j^i|$ .

We have also that  $b = \frac{2L_1}{\alpha}$ , for both orientations.

The points  $P_1$  and  $P_2$  of Figure 3, correspond to the observation points in each orientation of the interferometer.

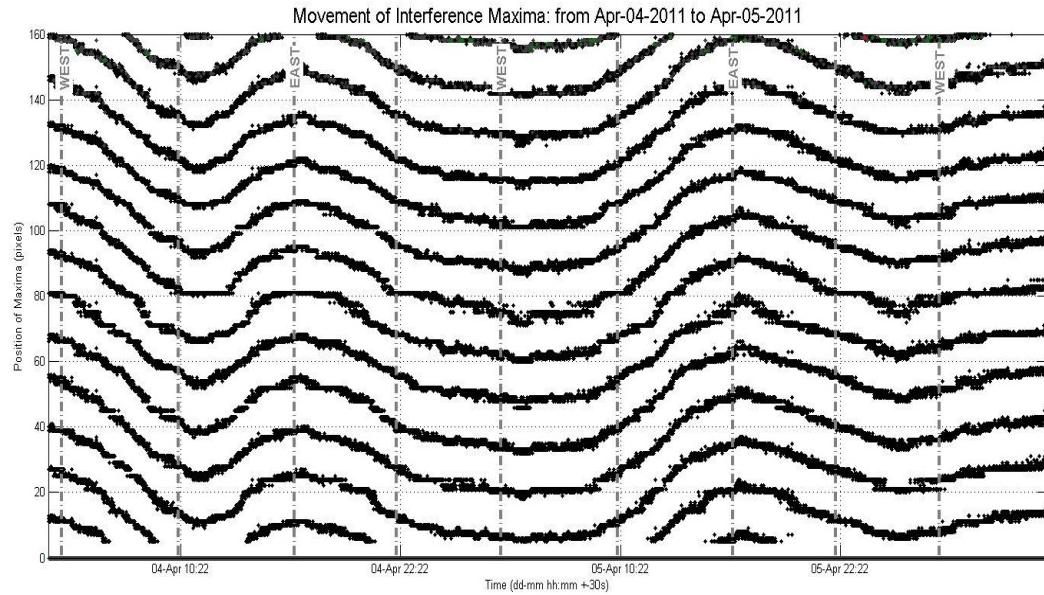
It can be deduced that the number  $N$  of fringes that the observer measures when the interferometer is rotated is given by

$$N = \frac{\left( |\overrightarrow{d_1^2}| - |\overrightarrow{d_2^2}| \right) - \left( |\overrightarrow{d_1^1}| - |\overrightarrow{d_2^1}| \right)}{\lambda} \quad (10)$$

Where  $\lambda$  is the wavelength of light.

From equation (10), because of the quadratic factor on  $|\overrightarrow{d_j^i}|$ , it can be shown that  $N$  scales approximately proportional to  $a^2$ .

This result has been experimentally verified by the authors. Although the details of such experiments are beyond the scope of this paper, it is interesting to show some *raw* data plots of the data obtained. An interferometer as the one previously described is left *at rest* in the laboratory, while the Earth rotates and orbits around the sun. Experiments have been going on for approximately four months, in different configurations, and the results are consistent among themselves and the theory.



**Figure 4 Verificación experimental de los resultados teóricos presentados. El eje vertical corresponde a la posición en pixeles del máximo de interferencia; el eje horizontal es el tiempo.**

In Figure 4, being time represented in the horizontal axis (30s precision), the lines that extend horizontally correspond to the vertical position, on the viewing screen of the interference pattern's

maxima. Vertical lines tagged with “East” and “West” denote the moments when the stellar object HIP54255 appears in the horizon on the earth’s sky, as seen from the laboratory (located N 10°32’, W 66°55’). The equatorial coordinates of this constellation are approximately equivalent to the direction of the velocity of the local group of galaxies with respect to CMB’s rest frame [2].

Given that the temperature was monitored (0,1K precision) so as the input voltage of the laser (0,1V precision) and no correlation was found with the observed fringe movement, the authors believe that the drifts are caused by natural laser instabilities, and because of the tridimensional nature of earths velocity, which also affect the optical paths, and are not studied in the above equations. Qualitatively, it can be seen an apparent correlation between fringe displacement and the position in the sky of HIP54255.

## Conclusions

It has been described and analyzed an interferometer sensitive to anisotropies of the speed of light. The most important difference of this interferometer with a M&M type interferometer is that light travels the distances between  $A'D'$  and  $B'C'$  in a *one way fashion*. When the interferometer is rotated (Figure 1 to Figure 2), the radii of spheres of light between source and observer increases, which explains the changes observed in the interference pattern. In a M&M type interferometer, each arm is traveled in a *two way fashion*: the radii of the spheres of light between source and observer are of the same magnitude on all orientations, thus no change in the interference pattern is seen.

It is important to notice that Lorentz’s Contraction was introduced, from the classical perspective, to account for the null result reported by M&M in their famous experiment. However, taking into account this effect (and thus maintaining the null result reported by M&M), and from the classical perspective (the existing of the ‘ether’ as the medium over which light propagates), it has been shown that using the proposed interferometer it is possible to detect changes in the interference pattern upon rotation, when  $v > 0$ .

We can also notice that because there is no relative motion between parts of the interferometer, according to the Special Theory of Relativity (STR) no changes in the interference pattern are to be expected when the interferometer is rotated. Using classical (pre-relativistic) notions it is shown that although there is no relative motion between parts of the interferometer, motion with respect to the ‘ether’ can be detected as fringe shifts, upon rotation of the interferometer.

It is interesting to mention that the Mach-Zehnder (MZ) interferometers, because of their one-way nature, are *also* sensitive to anisotropies in the speed of light. In fact, the interferometer described in this paper could be understood as a variation of the MZ type. Yet more interesting is to think a MM as a MZ ‘folded upon itself’, with the difference that the same beam splitter is used to divide and to recombine the beams of light. This is equivalent to bring together the beam splitters of a MZ (realigning the mirrors correspondingly). While the beam splitters are brought together, the MZ interferometer transforms gradually into a MM interferometer, also gradually transforming its one-way nature into a two-way. Just before the beam splitters are in the exact same positions, the deformed MZ interferometer looks like a slightly unaligned MM interferometer, with vestiges of sensibility to anisotropies. As has already been told in this paper, the misalignment is proportional to the number of fringes that shift when the interferometer is rotated. It is the opinion of the authors that this is the main reason why experiments using MM type interferometers have not measured identically null results, but always report velocities with magnitudes much smaller than expected (unless, of course, the interferometer is perfectly aligned).

## References

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- 2 A. Kogut, C. Lineweaver, G.F. Smoot, C. L. Bennett, A. Banday, et al. Dipole Anisotropy in the COBE DMR First-Year Sky Maps. *Astrophys.J.* 419 (1993) 1